METHOD OF ATTACHING A SEAT BELT TO A SEAT BELT TENSION SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

The instant application claims the benefit of prior U.S. Provisional Application Serial No. 60/394,815 filed on July 10, 2002, which is incorporated herein by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 illustrates a top-view of an occupant wearing a seat belt in a vehicle seat, wherein the seat belt incorporates a seat belt tension sensor;

FIG. 2 illustrates a front-view of a vehicle seat upon which a child seat is secured by a seat belt, wherein the seat belt incorporates a seat belt tension sensor and the vehicle seat incorporates a seat weight sensor;

FIG. 3 illustrates scenarios associated with various seat belt tensile load ranges;

FIG. 4 illustrates a cross-sectional view of seat belt tension sensor;

FIG. 5 illustrates a prior art method of attaching a seat belt to a seat belt tension sensor;

FIG. 6 illustrates an embodiment of an improved method of attaching a seat belt to a seat belt tension sensor;

FIG. 7 illustrates a plot of seat belt tension sensor output as a function of seat belt tension comparing the prior art and improved attachments of a webbing of a seat belt to a seat belt tension sensor;

FIG. 8 illustrates a detail of a portion of a loop of webbing secured by a second set of stitches, for the embodiment of **Fig. 6**;

FIG. 9 illustrates another method of attaching a seat belt to the seat belt tension sensor, wherein portions of a loop of webbing are folded and stitched separately;

FIG. 10 illustrates yet another method of attaching a seat belt to the seat belt tension sensor, wherein a loop of webbing is bunched or folded within a ring;

FIG. 11 illustrates yet another method of attaching a seat belt to the seat belt tension sensor, wherein portions of a loop of webbing are bunched or folded within separate rings;

FIG. 12 illustrates yet another method of attaching a seat belt to the seat belt tension sensor, wherein portions of a loop of webbing are bunched or folded within separate ring portions that are separated from one another;

FIGs. 13a and **13b** illustrate yet another method of attaching a seat belt to the seat belt tension sensor, wherein a loop of webbing is bunched or folded within a sleeve that engages a carriage of the seat belt tension sensor;

FIGs. 14a and **14b** illustrate yet another method of attaching a seat belt to the seat belt tension sensor, wherein a loop of webbing is bunched or folded around a thimble that engages a carriage of the seat belt tension sensor;

FIGs. 15a and **15b** illustrate yet another method of attaching a seat belt to the seat belt tension sensor, wherein a loop of webbing is bunched or folded around a thimble portion of a carriage of the seat belt tension sensor; and

FIGs. 16a and **16b** illustrate yet another method of attaching a seat belt to the seat belt tension sensor, wherein the opening of the housing and anchor plate are adapted to reduce or prevent friction from the loop of webbing therewith.

DESCRIPTION OF EMBODIMENT(S)

There exists a need for measuring a tensile load in a flexible load bearing element, such as a webbing, cable, rope or thread. As an example, there exists a need to measure a tensile load in a seat belt used in vehicular safety restraint system, wherein the seat belt load measurement can be used to distinguish a type of object secured by the seat belt, or can be used to compensate for the affect of seat belt loads upon a measurement of seat weight from a seat weight sensor in the seat base.

Referring to **Fig. 1**, a **seat belt tension sensor 10** is operatively coupled to a **webbing 12** of a **seat belt 14**, for measuring a tensile load therein.

The **seat belt 14** illustrated in **Fig. 1** – generally known as a "three-point" seat belt with a continuous loop lap/shoulder belt -- comprises a **lap belt portion 16** and a **shoulder belt portion 18**, wherein one end of the **lap belt portion 16** the **seat belt 14** is attached at a **"first**

point" **20** to a **first anchor 22** secured to the **vehicle frame 24**, one end of the **shoulder belt portion 18** is attached at a **"second point" 26** to a **seat belt retractor 28** secured to the **vehicle frame 24**, and the other ends of the **lap belt portion 16** the **shoulder belt portion 18** are located where the **seat belt 14** passes through a **loop 30** in a **latch plate 32** that engages with a **buckle 34** that is attached at a **"third point" 36** to a **second anchor 38** secured to the **vehicle frame 24.** The **shoulder belt portion 18** passes through a **"D-ring" 40** operatively connected to the **vehicle frame 24** that guides the **shoulder belt portion 18** over a shoulder of the **occupant 42.**

The **seat belt retractor 28** has a spool that either provides or retracts **webbing 12** as necessary to enable the **seat belt 14** to placed around the **occupant 42** sufficient to engage the **latch plate 32** with the **buckle 34**, and to remove excess slack from the **webbing 12**. The **seat belt retractor 28** provides a nominal tension in the **seat belt 14** so that, responsive to a crash that causes the **seat belt retractor 28** to lock the **webbing 12** thereby preventing further withdrawal, the **occupant 42** is restrained by the **seat belt 14** relatively earlier in the crash event than would occur had there been slack in the **seat belt 14**. During the crash event, when restraining the **occupant 42**, the **webbing 12** of the **seat belt 14** can be exposed to a relatively high tensile load, the magnitude of which depends upon the severity of the crash and the mass of the **occupant 42.**

Referring to **Fig. 2**, the **lap belt portion 16** of a **seat belt 14** may also be used to secure a **child seat 44**, such as a **rear facing infant seat 44'**, to the **vehicle seat 46**, wherein a **locking clip 48** may be used to prevent the **shoulder belt portion 18** from sliding relative to the **lap belt portion 16** proximate to the **latch plate 32**. In this case, the **lap belt portion 16** is typically secured relatively tight – with an associated tensile load greater than the associated comfort limit for an adult – so as to hold the **child seat 44** firmly in the **vehicle seat 46** by compressing the seat cushion thereof, and the **shoulder belt portion 18** is not otherwise relied upon for restraint.

Accordingly, the tensile load in the **webbing 12** of the **seat belt 14** can be used to discriminate an object on the **vehicle seat 46**, wherein a tensile load greater than a threshold would be indicative of a **child seat 44**. Referring to **Figs. 1** and **2**, a **seat belt tension sensor 10** is operatively coupled to a **lap belt portion 16** of a **webbing 12** of a **seat belt 14** at a particular seating location. The **seat belt tension sensor 10** and a **crash sensor 50** are operatively coupled to a **controller 52** that is adapted to control the actuation of a **restraint actuator 54** – e.g., an **air**

bag inflator 54' -- of a **safety restraint system 56** located so as to protect an occupant at the particular seating location. If the tensile load sensed by the **seat belt tension sensor 10** is greater than a threshold, then the **restraint actuator 54** is disabled by the **controller 52** regardless of whether or not a crash is detected by the **crash sensor 50**. If the tensile load sensed by the **seat belt tension sensor 10** is less than a threshold, then the **restraint actuator 54** is enabled by the **controller 52** so that the **restraint actuator 54** can be actuated responsive to a crash detected by the **crash sensor 50**. Alternately, for a controllable **restraint actuator 54**, e.g. a multi-stage **air bag inflator 54'**, the timing and number of inflator stages inflated can be controlled to effect a reduced inflation rate rather than disabling the **air bag inflator 54'** responsive to the **seat belt tension sensor 10** sensing a tensile load greater than a threshold.

Referring to **Fig. 2**, a **seat belt tension sensor 10** may be used in conjunction with at least one other **occupant sensor 58**, e.g. a **seat weight sensor 60**, to control the actuation of a **safety restraint system 56**. The **seat weight sensor 60** may operate in accordance with any of a variety of known technologies or embodiments, e.g. incorporating a hydrostatic load sensor, a force sensitive resistor, a magnetostrictive sensing elements, or a strain gage load sensor, which, for example, either measure at least a portion of the load within the **seat cushion 62**, or measure the total weight of the seat. In either case, a tensile load in the **seat belt 14** that is reacted by the **vehicle frame 24** acts to increase the load upon the **seat cushion 62**, thereby increasing the apparent load sensed by the **seat weight sensor 60**. The apparent load is increased by each reaction force, so that a given tensile load in the **seat belt 14** could increase the apparent load sensed by the **seat weight sensor 60** by as much as twice the magnitude of the tensile load. Accordingly, in a system with both a **seat belt tension sensor 10** and a **seat weight sensor 60**, the seat weight measurement from the **seat weight sensor 60** can be compensated for the effect of tensile load in the **seat belt 14** so as to provide a more accurate measure of occupant weight, by subtracting, from the seat weight measurement, a component of seat weight caused by, or estimated to have been caused by, the tensile load measured by the **seat belt tension sensor 10**. If the seat weight measurement from the **seat weight sensor 60** is not compensated for the effect of the tensile load in the **seat belt 14**, a **child seat 44** secured to a **vehicle seat 46** with a **seat belt 14** could cause a load on the **seat weight sensor 60** that is sufficiently high to approximate that of a small adult, so that an uncompensated seat weight measurement might cause the

associated **restraint actuator 54** to be erroneously enabled in a system for which the **restraint actuator 54** should be disabled when a **child seat 44** is on the **vehicle seat 46**.

In a system that compensates for the affect of seat belt tension on an **occupant sensor 58**, the **seat belt tension sensor 10**, the **occupant sensor 58**, --e.g. a **seat weight sensor 60**, -- and a **crash sensor 50** are operatively coupled to a **controller 52** that is adapted to control the actuation of a **restraint actuator 54** – e.g., an **air bag inflator 54'** -- of a **safety restraint system 56** located so as to protect an occupant at the particular seating location. If the tensile load sensed by the **seat belt tension sensor 10** is greater than a threshold, then the **restraint actuator 54** is disabled by the **controller 52** regardless of whether or not a crash is detected by the **crash sensor 50** or regardless of the measurement from the **occupant sensor 58**. If the tensile load sensed by the **seat belt tension sensor 10** is less than a threshold, then the **restraint actuator 54** is enabled or disabled by the **controller 52** responsive to a measurement from the **occupant sensor 58**, which may be compensated responsive to the tensile load sensed by the **seat belt tension sensor 10**. If the **restraint actuator 54** is enabled, then the **restraint actuator 54** can be actuated responsive to a crash detected by the **crash sensor 50**. Alternately, for a controllable **restraint actuator 54**, e.g. a multi-stage **air bag inflator 54'**, the timing and number of inflator stages inflated can be controlled to effect a reduced inflation rate rather than disabling the **air bag inflator 54'** responsive to measurements from the **occupant sensor 58** and the **seat belt tension sensor 10**.

Referring to **Fig. 3**, the loads to which a **seat belt 14** is normally exposed can be classified into four ranges as follows: 1) a **low range (I)** comprising tensile loads associated with the **seat belt 14** being placed directly around a human, 2) a **low-intermediate range (II)** comprising tensile loads associated with the restraint a **child seat 44**, 3) a **high-intermediate range (III)** comprising loads associated with non-crash vehicle dynamics, e.g. braking or rough roads, and 4) a **high range (IV)** comprising tensile loads associated with restraint forces of a crash event. The **low range (I)**, for example, would normally be limited by the maximum tensile load that an **occupant 42** could comfortably withstand. The **low-intermediate range (II)**, for example, would normally be limited by the maximum tensile load that a person could apply to the **seat belt 14** while securing a **child seat 44** to the **vehicle seat 46**. Notwithstanding that the **seat belt 14** and associated load bearing components can be subject to the **high range (IV)** tensile loads, a **seat belt tension sensor 10** would be useful for controlling a **safety restraint**

system 56 if it were capable of measuring **low-intermediate range (II)** tensile loads associated with securing a **child seat 44** to a **vehicle seat 46.**

Referring to **Figs. 4-6**, an exemplary **seat belt tension sensor 10** comprises an assembly of an anchor plate 102, a housing 104, a carriage 106 moveable within the **housing 104**, and a pair of helical compression springs 108 disposed between the **carriage 106** and the **housing 104** within associated spring guide cavities 110. The **housing 104** engages and is restrained by a pair of fingers 112 extending from the **anchor plate 102**, and is also attached to the **anchor plate 102** with a screw. Openings 114 in the **carriage 106**, **housing 104** and **anchor plate 102** are aligned so as form an **opening 114** in the assembly to which is attached a loop 116 of **webbing 12** of a **seat belt 14**. The **anchor plate 102** further comprises a mounting hole 118 by which the **seat belt tension sensor 10** is attached with an **anchor bolt 120** to a **vehicle frame 24.** A proximity or displacement sensor 122 measures the position of the **carriage 106** relative to the **anchor plate 102**. For example, a Hall-effect sensor 122.1 or the like, operatively coupled to the **housing 104**, cooperates with a pair of magnets 124 that are mounted in the **carriage 106** so as to provide an output signal that is responsive to the position of the **carriage 106** with respect to the **anchor plate 102.**

In operation, a tension in the **webbing 12** of the **seat belt 14** is applied to the **carriage 106** and is reacted by the **carriage 106** through the **helical compression springs 108**, the **housing 104**, the **anchor plate 102** and the **anchor bolt 120**. The displacement of the **carriage 106** is responsive to the tension, and is sensed by the **Hall-effect sensor 122.1**, the output of which is responsive to the strength of the magnetic field thereat -- generated by the **magnets 124** that move with the **carriage 106** -- which provides a measure of displacement of the **carriage 106** relative to the **housing 104** and **anchor plate 102**, which in turn provides a measure of seat belt tension based upon the effective compliance of the **helical compression springs 108.** Accordingly, a tension in the **seat belt 14** causes a motion of the **carriage 106**, and this motion is calibrated by the effective force-displacement characteristic of the **helical compression springs 108**, which provides for generating a measure of seat belt tension from a measure of displacement of the **carriage 106** relative to the **housing 104** and **anchor plate 102.** The **webbing 12** of a **seat belt 14** moves with the **carriage 106** relative to the **housing 104** responsive to a tension in the **seat belt 14**. More particularly, the **webbing 12** slides over the surface of the **seat belt tension sensor 10** (e.g. **housing 104** and **anchor plate 102**) responsive

to this motion, thereby generating associated frictional forces in a direction that is opposite to the direction of motion. These frictional forces cause an associated hysteresis in the output signal from the **Hall-effect sensor 122.1**, i.e. a dependence of the output upon whether the seat belt tension is increasing or decreasing, as illustrated in **Fig. 7**.

Stated in another way, the **seat belt tension sensor 10** comprises an assembly of a first portion of the **seat belt tension sensor 10**, and a **carriage 106** moveable relative thereto, wherein **openings 114** in the first portion -- i.e. **openings 114** in the **anchor plate 102** and **housing 104** -- cooperate with the **opening 114** in the **carriage 106**. A **seat belt 14** looped through the **opening 114** in the first portion of the **seat belt tension sensor 10**, if not otherwise constrained, is susceptible of generating non-negligible frictional forces and associated hysteresis as a result of rubbing against either a side or an outer surface of the **opening 114** in the first portion of the **seat belt tension sensor 10**, responsive to a tension load applied to the **seat belt 14**.

Referring to **Fig. 5**, in accordance with a prior art method of attaching a **seat belt 14** to a **seat belt tension sensor 10**, the **webbing 12** is looped through the **opening 114** in the **carriage 106, housing 104** and **anchor plate 102** of the **seat belt tension sensor 10**, and the two resulting portions of the **webbing 12** (on either side of the **opening 114**) are laid against one another and sewn together at a **first set of stitches 126** across the width of the **webbing 12**, so as to form a closed **loop 116** of **webbing 12** through the **opening 114** and around the **seat belt tension sensor 10**. The **first set of stitches 126** are adapted to be sufficiently strong to safely withstand the full range of tension loads to which the **webbing 12** is exposed during the operation of the **seat belt 14**. For the width of the **opening 114** substantially narrower than the nominal width of the **webbing 12**, the **webbing 12** of the **loop 116** is bunched or folded together within the **opening 114**, and **fans out 128** from the **opening 114** to the **first set of stitches 126**, on both sides of the **seat belt tension sensor 10**. For example, the width of the **opening 114** may be about half the nominal width of the **webbing 12**, or less. The bunching of the **webbing 12** within the **opening 114** generates lateral forces against the sides of the **opening 114** in the **housing 104** and/or **anchor plate 102** when a tension is applied to the **webbing 12**, which cause associated frictional forces that oppose motion of the **webbing 12** relative to the **housing 104**, which reduce the apparent tension sensed by the **seat belt tension sensor 10** as the tension is in the **webbing 12** is increased, and which increase the apparent tension sensed by the **seat belt**

tension sensor 10 as the tension is in the **webbing 12** is decreased, thereby causing substantial measurement hysteresis as is illustrated in **Fig. 7** in the plot of the output of the **Hall-effect sensor 122.1** of the **seat belt tension sensor 10** as a function of the associated seat belt tension for the seat belt attachment illustrated in **Fig. 5**.

Referring to **Fig. 6**, illustrating an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, the **webbing 12** of the **loop 116** is bunched or folded together within the **opening 114**, and is further bunched or folded above the **opening 114**, e.g. where the **webbing 12** follows the outside surfaces of the **seat belt tension sensor 10**, so as to prevent the **webbing 12** from rubbing against the sides of the **housing 104** and/or **anchor plate 102**. For example, in the embodiment illustrated in **Fig. 6**, a **second set of stitches 130** are provided in the **loop 116**, between the **first set of stitches 126** and the **restraining end 132** of the **housing 104** within the **loop 116**, so as to prevent the bunched or folded **webbing 12** from fanning out from the **opening 114**. Instead, the **second set of stitches 130** substantially prevent the width of the bunched or folded **webbing 12** within the **opening 114** from expanding with increasing seat belt tension, thereby reducing associated frictional forces against the sides of the **opening 114** in the **anchor plate 102** or **housing 104** that cause associated measurement hysteresis. Referring to **Fig. 7**, the measurement hysteresis for the embodiment of **Fig. 6** is substantially less than that for the embodiment of **Fig. 5**.

There are various means that may be used to constrain the width of the **webbing 12** along the **seat belt tension sensor 10**. In the embodiment of **Fig. 6**, both **portions 134, 136** of the **webbing 12** of the **loop 116** are folded and stitched together with a **second set of stitches 130**, as further illustrated in **Fig. 8**.

Referring to **Fig. 9**, in another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, the individual **portions 134, 136** of the **webbing 12** of the **loop 116** is separately folded and sewn with respective **third 138** and **fourth 140 sets of stitches**.

Referring to **Fig. 10**, in yet another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, both **portions 134, 136** of the **webbing 12** of the **loop 116** are bunched or folded within a **ring 142**, e.g. a metal ring, located between the **seat belt tension sensor 10** and the **first set of stitches 126**, wherein the **ring 142** may be either

closed as illustrated in **Fig. 10**, or open -- e.g. along a portion of one side thereof -- but with sufficient rigidity and shaped so as to maintain the bunched or folded condition of the **webbing 12** within the **ring 142**.

Referring to **Fig. 11**, in yet another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, each **portion 134, 136** of the **webbing 12** of the **loop 116** is bunched or folded within a respective **ring 144, 146**, e.g. respective metal rings, located between the **seat belt tension sensor 10** and the **first set of stitches 126**, wherein one or both **rings 144, 146** may be either closed as illustrated in **Fig. 11**, or open -- e.g. along a portion of one side thereof -- but with sufficient rigidity and shaped so as to maintain the bunched or folded condition of the **webbing 12** within the respective **rings 144, 146**.

Referring to **Fig. 12**, in yet another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, each **portion 134, 136** of the **webbing 12** of the **loop 116** is bunched or folded within a respective **ring portion 148, 150**, located between the **seat belt tension sensor 10** and the **first set of stitches 126**, wherein the **ring portions 148, 150** are separated by a **spacer 152** that keeps the **loop 116** sufficiently open so as to reduce rubbing and associated frictional forces between the **loop 116** and the surfaces of the **housing 104** and/or **anchor plate 102**, wherein one or both **ring portions 148, 150** may be either closed as illustrated in **Fig. 12**, or open -- e.g. along a portion of one side thereof -- but with sufficient rigidity and shaped so as to maintain the bunched or folded condition of the **webbing 12** within the respective **ring portions 148, 150**.

Referring to **Figs. 13a** and **13b**, in yet another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, the **loop 116** of **webbing 12** is fed through a **sleeve 154**, e.g. of plastic, that engages the **carriage 106** of the **seat belt tension sensor 10** and keeps the **webbing 12** bunched or folded therein so as to prevent the **loop 116** from rubbing against the sides of the **opening(s) 114** in the **housing 104** and/or **anchor plate 102**. An at least semi-rigid **sleeve 154** could be shaped so as to keep the **loop 116** open, so as to reduce or prevent friction caused by the **loop 116** rubbing against the face(s) of the **housing 104** and/or **anchor plate 102**. Referring to **Figs. 14 a** and **14b**, alternately a **thimble 156** could be used instead of a **sleeve 154**. Referring to **Figs. 15a** and **15b**, alternately a **thimble portion 158** could be incorporated in the **carriage 106** to engage a bunched or folded **webbing 12** of the **loop**

116 and to thereby reduce or prevent friction caused by the **loop 116** rubbing against the face(s) of the **housing 104** and/or **anchor plate 102**.

Referring to **Figs. 16a** and **16b**, in yet another embodiment of an improved method of attaching a **seat belt 14** to the **seat belt tension sensor 10**, the **openings 114** in the **housing 104** and **anchor plate 102** are adapted to be sufficiently wider than that of the **opening 114** in the **carriage 106** so as to keep the bunched or folded **webbing 12** of the **loop 116** within the **opening 114** of the **carriage 106** from rubbing against the sides of the **openings 114** in the **housing 104** and **anchor plate 102** when the **seat belt 14** is tensioned. This may be combined with either a **flange 160** -- or, as illustrated in **Fig. 15**, a **thimble portion 158** -- on the **carriage 106** so as to reduce or prevent friction caused by the **loop 116** rubbing against the face(s) of the **housing 104** and/or **anchor plate 102**.

While specific embodiments have been described in detail in the foregoing detailed description and illustrated in the accompanying drawings, those with ordinary skill in the art will appreciate that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. For example, rather than bunching or folding a portion of the webbing, the webbing may be woven so as to locally narrow that portion, wherein the warp fibers are bunched together in the narrowed portion of the webbing and the associated weft fibers are interlaced therewith accordingly. Furthermore, the friction and associated hysteresis between webbing and the seat belt tension sensor may be reduced by interposing a relatively low friction coating or material at a location of sliding contact between the webbing and the seat belt tension sensor. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention, which is to be given the full breadth of the appended claims and any and all equivalents thereof.

We claim: